

Profiles of Level 5 CMMI Organizations

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Many firms that have achieved Level 5 using the Software Engineering Institute's Capability Maturity Model® Integration (CMMI®) have taken a different tact in justifying their process improvement initiative's budget. This article summarizes the profiles of high maturity organizations and explains how they go about justifying their budgets. The article also provides insight into the differing tactics that these firms use to win the battle of the budget and the reasons for them.

During the past two decades, a number of professionals in the software community have argued for investing in process improvement [1, 2]. Those following the mantra of embracing frameworks like the Software Engineering Institute's CMM [3] and CMMI [4] have touted the benefits of process improvement and argued that the costs are fully justified [5, 6]. While there are some definitive works that portray the cost/benefits [7, 8], little has been done to study the return on investment (ROI) of high maturity organizations that have reached Level 5. Many practitioners within the industry that we have talked with wonder what happens when high maturity organizations move into the maintenance mode at Level 5. Managers wonder what the costs/benefits are and what others' experiences have entailed. Process groups want to know how to justify the costs of sustaining a process improvement pro-

gram in a maintenance mode. In fact, everyone we spoke with wanted to be able to set realistic expectations for their continuous improvement efforts. However, the only data that seemed available to them referred to the benefits associated with reaching higher CMM [9] and/or CMMI maturity levels [10]. Based on our research, we can conclude that little data exists that firms can use to justify maintaining their process improvement programs at either CMM or CMMI Level 5. In addition, those that report about their performance typically mix CMM and CMMI data in their analysis (see CMMI performance results about Level 5 firms on the Software Engineering Institute [SEI] Web site at <www.sei.cmu.edu>).

The Study

Early last year, we embarked on a study to develop answers to these questions. Three process groups from different organiza-

tions sponsored an effort aimed at using historical data to justify their process improvement maintenance budgets at CMMI Level 5. To begin, we contacted those Level 5 firms within the United States listed on the SEI's Web site with which we had a relationship and asked them for permission to use their data without attribution to develop our results. For the past 20 years, we have been working with organizations like those that sponsored our effort to develop cost, productivity, and quality benchmarks [11]. For the most part, the 11 firms and 19 organizations that agreed to supply us during the past 18 months with data shared the profile summarized in Table 1. As the table illustrates, the organizations surveyed were large, distributed, hierarchical, and primarily working within either the aerospace or telecommunications industries. Their primary motivation for being Level 5 was both to be competitive (e.g., most of their competitors perceived as Level 5 are using CMMI), and able to deliver what they promised to their customers on time and within budget (i.e., improve their ability to predict and control their system/software engineering activities).

Foreign firms were specifically excluded from our analysis because all those involved felt that they would bias the results. To confirm this tendency, we analyzed the resulting databases with and without foreign contributions and discovered that it was a better fit with the foreign data eliminated because the underlying databases were more homogeneous. For example, data on Level 5 firms collected from India was primarily from United States subsidiaries developing software for commercial applications as opposed to aerospace applications. These organizations were mid-sized (averaged about 250 to 500 engineers), and minimal system and hardware engineering was performed. Based on these facts, we agreed not to include foreign data. However, we may decide differently in the future as we populate our databases.

Table 1: Profile of United States Level 5 Organizations Used in Analysis

Characteristic	Explanation
Industry	Aerospace
Major Products	Aircraft, missiles, satellites, spacecraft, tactical systems, weapons systems, etc.
Management Organization	Hierarchical with many layers of management. Matrix approach used for the most part with program management separate from contracts and engineering. Engineering budgets cover Research and Development and investments to develop skills (training) and processes.
Engineering Workforce Size	Average size of performing organizations with more than 1,000 engineers/location.
Number of Locations	Average greater than five with workforce distributed either based on product lines or legacy firms that they had acquired.
Process Framework Embraced	CMM and CMMI – all were Level 5 and all had transitioned to the use of the CMMI (some were being re-evaluated for Level 5).
Process Organization	Process group with a staff of approximately five, and a budget averaging about \$2 million per year (besides funding staff, they provided budgets for training, tools, the Process Asset Library, etc.).
Years Pursuing Process Improvement Initiatives	More than 10 years on average working to raise the level of the organization to Level 5 first using the CMM and now the CMMI.
Investment Climate	Process improvement viewed as a customer requirement; emphasis on minimizing overhead expenses.

Determining the Costs/Benefits

We next analyzed our databases to determine the costs needed to maintain and sustain a process improvement program and the benefits that resulted at Level 5. Costs and benefits were collected by scenario as shown in Tables 2 and 3 and briefly defined as the following:

- **Optimization and Maintenance.**

Rather than focusing on achieving higher maturity levels, the process staff focuses on maintaining processes and perfecting their use. They modify processes, optimize them and increase their holdings in their Process Asset Libraries. They focus on making processes work better by incorporating feedback based on operational use.

- **Focus on Finding Defects Out-of-Phase.** The process staff reinvents itself and places emphasis on embracing six sigma techniques to prevent defects from occurring earlier in the life cycle. They capitalize on their statistical process control experience to reduce escapes (defects escaping from one phase to the next; e.g., a requirements defect that escaped and was not found until the design phase).

For completeness, we have included the cost/benefit data previously collected as part of another one of our ongoing efforts relative to starting up a process program and reaching higher maturity levels as shown in Tables 2 and 3 [12]. These two additional process improvement scenarios are briefly defined as the following:

- **Starting Up.** Initiating a process improvement program, selling the concept, staffing the process team, writing the processes, and providing the training and project support needed to fan out throughout the organization.

- **Reaching for Higher Maturity Levels.** Moving from one level to the next in process maturity includes the effort to satisfy the framework requirements and survive and recover from a CMMI assessment [13]. As Table 2 shows, reaching the next level in process maturity involves a great deal of effort and takes between 15 and 21 months to achieve.

Level 5 activities by design are aimed at optimizing existing processes, not developing, introducing or institutionalizing new ones. Statistical process control techniques are used to determine which processes are working well and which are not. Those maintaining processes use this information to focus their resources on

Scenario	Range of Cost/Time (\$ expended/months to complete)+		
	Small	Medium	Large
Starting Up	\$1 to 1.5M/ 18 to 20 months	\$1.5 to 2.5M/ 18 to 22 months	\$2.5 to 3M/ 20 to 24 months
Reaching the Next Level in Process Maturity	\$0.75 to 1M/ 12 to 16 months	\$1 to 1.5M/ 15 to 18 months	\$1.5 to 2M/ 18 to 21 months
Optimization and Maintenance	\$0.35 to 0.5M/ 12 months++	\$0.5 to 0.75M/ 12 months++	\$0.75 to 1M/ 12 months++
Out-of-Phase Defect Focus	\$0.5 to 0.78M/ 12 months++	\$0.78 to 1.0/ 12 months++	\$1.0 to \$1.3M/ 12 months++

+ Costs incurred are those for the process improvement program. Burdened cost per person-month average \$20K (2005 year \$). Staff involved in process improvement programs in large firms tends to be very senior and therefore very expensive [i.e., groups are typically staffed with opinion leaders who have the respect of the workers based on their accomplishments with 20+ years of experience].

* Typical staff assigned to process group between four and six equivalent heads; three work process development, and three provide project support either as part of the process group or within project organization.

++ Budgeted/reported on an annual basis.

Table 2: Range of Costs/Time by Scenario for Military Systems by Organization Size

making processes work better through training, mentoring, and improving organizational support.

The following important points amplify some of the points raised within Tables 2 and 3:

- Process improvement budgets for starting up a program and focusing on reaching the next level of process maturity are two to three times higher than those for optimization and maintenance. This makes sense based on

Table 3: Range of Benefits for Military Systems by Scenario

Benefit Category	Benefit Range/Time (\$ saved/months to realize)+			
	Starting Up	Reaching the Next Level	Optimization and Maintenance	Out-of-Phase Defect Focus
Cost Avoidance	2 to 12% savings/ 18 to 20 months*	3 to 16% savings/ 16 to 18 months	Flat	Finding escapes results in 6 to 8% savings/annually
Productivity Gains	5 to 10% annually*	8 to 18% annually	Flat	1 to 3% annually
Faster Time-to-Market	Not applicable during startup	Improved ability to predict/meet schedule	Improved ability to predict/meet schedule	Improved ability to predict/meet schedule
Quality Improvement	Not enough data	8 to 18% fewer errors/post release	12 to 26% fewer errors/post release	18 to 30% fewer escapes
Estimated ROI	15 to 51%/ 18 to 20 months	18 to 103%/ 15 to 18 months	12 to 36%/ annually	24 to 138%/ annually
Minimum Time (to achieve ROI)	18 months	15 months	Performed on an annual basis	Performed on an annual basis
Other benefits:				
▪ Improved customer satisfaction	Fewer customer complaints	Increased customer praise	Continued customer praise	Customer views you as best in class
▪ Improved competitive positioning	Perceived competitive gaps closed	Perceived competitive gaps closed	Continued commitment to process maintained	Perceived competitive advantage
▪ Other				

+ Benefits computed for the entire engineering organization at large. Burdened cost per person-month is less than that for the process improvement effort averaging \$15K (2005 year \$) (Note – staff involved in the development organization are typically less qualified than those involved in the process group).

* Many organizations that start up a process program make the mistake of promising results in the first year. Because of learning curves and start-up problems, positive results do not accrue until the second year when the appraisal is conducted and confirmation is made that they have realized their goals.

++ Budgeted/reported on an annual basis.

the relative efforts involved. However, just like many software development efforts, many process groups claim premature victory when they get appraised at Level 5. While most organizations embrace the processes, some object to them. In addition, new projects need considerable start-up support that the process group is expected to provide. Finally, because benefits are not as visible, there is pressure from upper management to dissolve the process group and use the overhead money that funds them for other purposes.

- Things seem to improve when Six Sigma techniques are coupled with process optimization and maintenance activities. Emphasis is placed on business performance rather than process goals as evidence is gathered to justify continuance and possible expansion of the program [14]. Budgets are justified because benefits are made visible and overhead funds are not diverted to other activities.
- Focusing on defects pays dividends as errors are found sooner and their root causes are systematically identified and addressed. Defects are caught in-phase (e.g., requirements errors are found and fixed during the requirements phase) and, as such, are easier, cheaper and simpler to remove. Emphasis is placed on defect prevention as well as reduction as processes are refined and optimized. New methods and tools like those for Six Sigma are acquired to automate these processes and make defect prevention part of the way work is done by performing organizations [15]. Designs are made more robust because root causes of persistent defects are eliminated, customer satisfaction is improved, and the organization's reputation for quality is enhanced.
- The ROI picture changes as the cost/benefits of the program are compiled. Instead of portraying the status quo, defect prevention is emphasized.

When the ROI for process improvement is computed using numbers like those provided in Table 3, the cumulative returns along with the list of other compelling factors can easily be used to convince executive management that their investments in process improvement make both good financial and technical sense. As an aside, we have found the use of the balanced scorecard to be a good way to present this data to executives in a holistic manner [16].

Looking at an example, one of our sponsors brought us in to assist them in preparing a briefing to senior management about the ROI of process improvement. When we delved further, we found that the briefing was aimed at convincing senior management not to eliminate the process group that had led their efforts during the past seven years in achieving a Level 5 rating. As expected, they had captured a great deal of cost, productivity and quality data as part of their metrics and statistical process control efforts. Unfortunately, the data validated the trends summarized in Tables 2 and 3; i.e., cost and productivity gains at Level 5 were flat and defect removal data alone did not justify the group's expenses (i.e., included the personnel assigned to the group along with training and facilitation expenses associated with fanning the process out to the projects). This group of five had been at Level 5 for four years, and was reappraised Level 5 CMMI last year. Senior management was not impressed by the business case presented to them during the last quarter and as a result were toying with the idea of dissolving the group and spending the money elsewhere (where ROI of the investment seemed better).

When we analyzed the organization's benefits data, we saw their focus was being placed on reducing the variation in organizational performance across projects – a function of process tailoring and utilization. The statistical data was very valuable

in this regard because it showed which processes were working well and which were not. We pointed out that there were high yield processes that had not been identified by the CMMI that still needed work; e.g., notably COTS management and software licensing. For example, we commented that we had saved one of our clients several million dollars annually by helping them put an enterprise licensing scheme in place for their software development tools [17]. We also suggested that more emphasis on preventing defects from escaping from one phase to another (escapes) could result in substantial increases in their yields. When we briefed these opportunities to the senior management, they became excited and tasked their process group to pursue additional process development, rollout, and defect prevention as part of their three-year plan. More importantly, budgets were approved as the process group took on this new mission.

Making the Business Case in High Maturity Firms

For large organizations like those involved in our survey, it is relatively easy to justify starting up or pursuing a process improvement initiative. However, it is more difficult to develop a business case when pursuing Level 5 optimization and maintenance activities [18]. Because cost and productivity gains are flat, firms often pare their process efforts down considerably at this stage. Those that reinvent themselves and place emphasis on Six Sigma techniques are the exception. For these organizations, the benefits derived by reducing defects across life-cycle stages (i.e., the number of escapes) seem sufficient to justify continuation of their efforts. However, such economies of scale may not be available for smaller organizations. As a result, building a business case under such circumstances becomes much more difficult.

Firms surveyed were somewhat surprised when we concluded that cost avoidance and productivity gains held steady once they reached Level 5. The easiest way to explain to them what was happening with cost and productivity was to make the following analogy. Say you go on a diet and lose 10 pounds during the first month. If you wanted to lose an additional 100 pounds at this rate, it would take you 10 months at 10 pounds per month. However, while losing weight is easy at first, it becomes more difficult as the pounds come off. Many times during your diet your weight stabilizes and it becomes extremely difficult to shed even a few

Table 4: Range of Cost to Find and Fix Defects In-Phase and Out-of-Phase

Injected Found	Range of Cost to Find and Fix Defects In-Phase and Out-of-Phase+			
	Inception	Elaboration	Construction	Transition
Inception	\$25 to \$100/defect			
Elaboration	\$100 to \$500/defect	\$50 to \$250/defect		
Construction	\$500 to \$1K/defect	\$250 to \$1.5K/defect	\$75 to \$500/defect	
Transition	\$8K to \$10K/defect	\$1.5K to \$5K/defect	\$500 to \$3K/defect	Not enough data

+ Defect costs computed for the entire engineering organization at large. Burdened cost per person-month again averages \$15K (2005 year \$).

additional pounds. Then, when you reach your weight loss goal, you have to go on a maintenance diet or else you will quickly gain the weight back. Cost avoidance and productivity gains are similar to weight loss. They occur quickly at first as you introduce processes and discipline. Once the processes are institutionalized, productivity gains and cost avoidance then stabilize and happen less quickly. As a result, when processes reach a steady state (e.g., at Level 5), cost avoidance and productivity gains become minimal. Similar to when you finish your diet, this stability should be expected.

For high maturity organizations at CMM and CMMI Level 5, justification for continuing process improvement work is handled differently. Based on the data we have collected and the experiences of firms polled, we can make the following observations:

- The emphasis of process improvement initiatives rightfully shifts from moving from one level of process maturity to the next to maintenance and optimization of the program.
- Organizations learn to use statistical process control information to optimize their use of resources. For example, projects shift personnel from one process to another when their control charts indicate that they are being successful with their practices (e.g., from inspections to test when inspections are working well).
- As a consequence of shifts in emphasis, cost avoidance and productivity gains tend to remain relatively flat for Level 5 organizations. The reason for this seems to be that high maturity organizations tend to focus on optimizing the use of existing processes instead of placing emphasis on reaching the next level of process maturity. Without the push to move ahead, the organization loses its drive and momentum.
- Cost avoidances tend to be negligible when organizations reach either SW-CMM or CMMI Level 5 because typically their resources are scaled back to pursue maintenance and optimization rather than the active pursuit of moving from one maturity level to the next.
- Defect rates and densities during both development and post-release phases of the life cycle tend to stabilize as organizational processes become institutionalized.
- In many organizations, process groups are disbanded. The process improvement charter is not dropped. Instead, it is picked up by other support groups (qual-

ity assurance, etc.) or initiatives (knowledge management, Six Sigma, etc.).

Domain of Applicability

The findings and observations shared in this article tend to be applicable to large projects where economies of scale make justification of investments in process improvement typically easy. This makes sense because most U.S. organizations that have been appraised Level 5 in the current Software Engineering Institute (SEI) process maturity database [19] are military/government agencies or their con-

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tractors (72 percent or 230 of those 321 reporting results). For the most part, these organizations share the organizational profile provided in Table 1. Even with this as the case, it is important to note that our conclusions may not be shared by either small firms or with foreign enterprises that make up 60 percent of the SEI appraisal database.

Conclusion

Successful process improvement groups reinvent themselves in high maturity organizations at CMMI Level 5. To justify their existence, they take on new charters and new initiatives to move their organizations forward and preserve their budgets. Those that we have observed to be successful defend their budgets based on reducing escapes, developing processes aligned with improving business functions (licensing, COTS management, etc.) and/or by achieving knowledge transfer goals. They embrace techniques like Six Sigma and

lean manufacturing, using them to focus on improving quality in addition to productivity, time-to-market or cost. Budget justification is relatively easy because, as noted in Table 4, they reduce escapes (e.g., finding and fixing defects out-of-phase) whose costs can be as great as 400 to one in the worst case.

The message from our analysis for high maturity organizations is loud and clear: Once they have institutionalized their processes, they should refocus their efforts on goals aligned with improving the business (improved product quality, etc.). As part of this reorientation, they should restructure their metrics program to capture additional data that can be used to measure the value of their business propositions. When implementing statistical process control at Level 5, they should embrace Six Sigma concepts to reduce defects in both their processes and products. They should focus on preventing defects by finding and fixing them by using techniques like orthogonal defect classification [20]. We believe that embracing Six Sigma and black belt concepts for both process and product improvement activities would be synergistic. Finally, Level 5 organizations should consider using the cost/benefits associated with finding and fixing defects as a means to justify their investments in process improvement. Use of such an approach makes it relatively easy to build the business case for process groups to pursue these revamped rather than new courses of action. ♦

Acknowledgements

I would like to thank the organizations and people that I collaborated with for their inputs and permission to release the results of our analysis. I also wish to thank the staff at the Systems and Software Consortium for their valuable inputs to this article. All who contributed make this a more powerful document.

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LETTER TO THE EDITOR

Dear CROSSTALK Editor,

Allow me to comment on the number one lesson learned that was in David Webb's October CROSSTALK article *All We Need to Know About Software Project Management, We Can Learn From Star Trek*.

I discovered early on, long before *Star Trek* ever aired episode one, that whilst I could make good estimates for how long it would take me to do a given software task, management always cut the estimate in half. Possibly because they thought everyone always overestimated, and certainly in part because they had overpromised the customer. There were certainly many people who did not know how to estimate and made wild guesses that helped reinforce management's need to question all estimates. Consequently, I started doubling my estimates only to discover that the time I lost waiting for others, attending meetings, doing administrivia, guarding turf, politicking for my manager, context switch inefficiency, yada yada, still took as long as the actual work.

Unfortunately, management thinks this unproductive work/time is *free* and takes no calendar time. As a result, I have made it a policy to always multiply my estimates by (at least) four. This lets management do their obligatory cut, and pro-

vides time for the non-productive tasks that always occur.

If management were truly CMM/CMMI conformant, they would allow adequate resources and encourage accurate allocation of same. In spite of all the CMM/CMMI hooplah and appraisals, far too many organizations are truly conformant only to the extent of having a certificate on the wall. So, until the millennium is upon us, I will continue to teach my students to multiply their estimates by four before committing to a task. I also warn them not to let others impose their estimates on us because the estimates will be both overly optimistic and will omit the overhead and time wasters that are required.

If my stratagem made it into *Star Trek III*, then apparently others have had the same experiences and came up with similar solutions.

As to miracles, maybe in *Star Trek*; but in my real-world experience, when the occasional miracle is performed management uses it as proof that their overly optimistic estimating is right and the workers are all lazy slackers who pad everything.

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